ESTIMATES OF ESCAPEMENT OF SOCKEYE SALMON INTO SPEEL LAKE IN 2003

by

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ABSTRACT

In 2003, the Douglas Island Pink and Chum Aquaculture Corporation operated a weir to count the number of sockeye salmon entering Speel Lake to spawn, and to mark about 20 percent of the fish counted with an adipose fin clip. Of the 7,014 sockeye salmon counted, 1,144 were marked. After the weir was dismantled, Alaska Department of Fish and Game personnel examined sockeye salmon on the spawning grounds, as part of a mark-recapture study to validate the weir counts. Two trips were conducted, and a total of 1,149 fish were examined, of which 168 had been marked at the weir. Fish smaller than 420 mm mid-eye to fork length were excluded from the calculations. The pooled Petersen estimate of escapement was 8,468 sockeye salmon, with a 95% confidence interval of 7,446 to 9,729 fish. Since the weir count is outside the confidence limits of the Petersen estimate, some of the larger sockeye salmon may have bypassed the weir. The difference between the weir count and the Petersen estimate may be due to problems in the first recapture event.

INTRODUCTION

Speel Lake is located south of the Taku River, adjacent to the Speel Arm of Port Snettisham (Figure 1). The ADF&G stream number for the outlet of Speel Lake is 111-33-034. Speel Lake has a surface area of 167.5 hectares (413.9 acres), and supports a small run of sockeye salmon (*Oncorhynchus nerka*). The lake is shallow with a maximum depth of 8.5 meters (28 feet) and a mean depth of 3 meters (10 feet). The shallower parts of the lake have extensive aquatic vegetation. Scree slopes, on the northeast side of the lake, plunge into the lake and provide the primary spawning habitat for sockeye salmon.

A weir has been used to count annual sockeye salmon escapements into Speel Lake from 1983 to 1992, and from 1995 to 2002, first by the Alaska Department of Fish and Game (ADF&G), then by the Douglas Island Pink and Chum Aquaculture Corporation (DIPAC). Following an analysis of the historical data, Geiger et al. (2003) recommended an escapement goal of 4,000 to 13,000 adult spawners for Speel Lake sockeye salmon. The Alaska Board of Fisheries adopted this goal, and the weir is the primary means of monitoring this management objective. By comparing daily amounts of rainfall from the Snettisham power plant with daily Speel Lake weir counts, Riffe and Clark (2003) demonstrated that heavy rainfall would trigger the passage of returning adult sockeye salmon past the weir, especially when little rain had fallen in the previous weeks. Riffe and Clark also concluded, except for 1983, 1995, and 2002, the weir was dismantled too early in the spawning migration to substantially enumerate it. Because of the influence of rainfall on fish passage, the degree of the past undercounting in most years is unknown. In order to obtain reliable estimates of escapement, ADF&G encouraged DIPAC to continue weir operations through the third week in September, and conducted a mark-recapture experiment to validate the weir count.

Mark-recapture validation studies are now standard practice in Southeast Alaska, and some form of mark-recapture experiment is used on every major ADF&G weir project. For Speel Lake, the mark-recapture study involves placing a visible mark on a proportion of the fish that are counted through the weir, and examining fish on the spawning grounds, noting the mark rate, and estimating the length distribution of spawning fish.

METHODS

DIPAC conducted the Speel Lake weir operations in 2003, in accordance with a project operational plan developed by ADF&G and reviewed by DIPAC. The Speel Lake weir was operational from July 14 to September 19. Data collected by weir personnel included number and species of fish counted through the weir, length sex and scales from sampled sockeye salmon, number of sockeye salmon marked, weather, water temperature, and water level. The data were recorded in “*Rite in the Rain*”© notebooks or Opscan© sheets, and summaries were transmitted daily to the Snettisham Hatchery office via VHF radio.

The weir was inspected regularly for holes and gaps; any holes or gaps that fish could swim through were corrected by pounding pickets down further or blocking holes using sandbags. Inspections increased during and after periods of high water.

Migrating salmon were counted through the weir by removing several pickets from an appropriate location on the weir face. Weir personnel would sit above the opening in the weir and tally fish passing through the weir by species during both daylight and evening hours. Fish passage by species, as well as other sampling data, was recorded in a "*Rite in the Rain*"© notebook kept specifically for that purpose, and then transferred to a daily weir count sheet after the day's tallies had been completed.

Marking

A fraction of the migrating sockeye salmon counted –about 20%– were marked and sampled for sex scales and length (mid-eye to fork of tail). Several times during the day, when the rest of the weir was fish-tight, weir personnel would remove pickets from the fish trap. When the trap was full or fish stopped entering the trap, the technicians would replace the pickets, and remove individual fish from the trap by dip net. The technicians then removed the adipose fin from each fish, and sampled for sex, scales and length between mid-eye to fork-of-tail (in mm). The four essential elements of this effort were: (1) marking a specific fraction of fish counted through the weir, irrespective of size (i.e., jacks included), (2) measuring the size of each marked fish for future comparisons with the size distribution of the recaptured fish, and (3) collecting a minimum of 800 scale samples from fish from throughout the run. At the end of the season, sockeye salmon length and associated scale data were sent to the ADF&G office in Douglas for scanning, data analysis, and archiving.

The project operational plan stipulated that, if marking percentage changed at the weir, sockeye salmon marked from that time forward would receive an additional auxiliary fin clip. Different auxiliary fin clips were to be used for each change in marking rate. Since the marking rate was fairly constant over the season, fish received only the adipose fin clip as a mark.

Recapture

The recapture portion of the study was originally slated to encompass three separate trips, taken in September and October. Due to adverse weather and prior commitments to other projects, the ADF&G recovery crew could only complete two trips. The first trip lasted from September 16 to September 18. Since the DIPAC technicians were then available, they assisted the ADF&G personnel, for a recovery crew of four. The second trip lasted from September 30 to October 1, and the 2 ADF&G employees comprised the recovery crew.

On each trip, the crew located fish on or near the spawning grounds, quickly deployed a seine around groups of fish and, sampled each captured fish. The crew sampled as many fish as possible. All fish were to be sampled for sex and length. The recovery crew recorded number of fish examined, the number of adipose fin clips, and the number of other fin clips observed in the data logbook. Data on fish believed to be one-ocean jack sockeye salmon were recorded separately from larger fish. The length cut-off between one-ocean jack salmon and larger fish was 400 mm from mid-eye to the fork in the tail. During the recovery phase, a sub-sample of 100 fish was to be sacrificed for otolith and brain parasite samples, preferably from spawned out fish or carcasses. Field data were recorded on "*Rite in the Rain*"© data logbooks, or on Opscan© sheets for age sex and length data.

During the first event, the weir crew examined all fish for adipose fin clips. A partial dorsal clip was applied to all fish caught on the first recovery event. If a fish was recaptured during the first trip (designated by a partial dorsal clip), it was ignored. Due to a misunderstanding, the recovery crew did not take length and sex samples. Since spawning had not yet commenced at the time of the first trip, no brain parasite or otolith samples were taken. The crew took two hundred genetic samples.

During the second trip, the recovery crew examined fish for adipose fin clips, and partial dorsal fin clips. Length and sex information was taken for all fish examined. One hundred fish were sampled for brain parasites and otoliths. The recovery crew gave all fish examined an anal fin clip.

Data Analysis

In order to determine whether rainfall had an effect on weir counts in 2003, I obtained daily rainfall data from Alaska Electric Light and Power for the Snettisham power plant, and made graphical comparisons with the daily weir counts.

The weir sampling (marking) and Speel Lake recovery data for sockeye salmon were analyzed using the statistical program "Stratified Population Analysis System" (SPAS) (Arnason et al. 1996). This program calculates chi-square diagnostic statistics, ML Darroch estimates, Darroch Moment estimates, least-squares estimates, and pooled Petersen estimates.

Conditions for accurate use of the above method for a closed population model are:

1. All adults have an equal probability of being marked; or
2. All adults have an equal probability of being inspected for marks; and
3. There is no recruitment to the population between weir and the spawning grounds upstream; and
4. There is no trap-induced behavior; and
5. Fish do not lose their marks and all marks are recognizable.

Experience has shown that probabilities of capture of sockeye and chum salmon change as their annual migration progresses. The multi-dimensional Darroch model adjusts for these temporal changes in probability of capture. Darroch's method cannot be used to adjust for size-selective capture at the weir or on the spawning grounds. Tests were to be used to detect, and if necessary, adjust calculations to remove bias from size-selective sampling. There should be no trap-induced behavior because different sampling gears are used in different sampling events. Fish were identified as marked fish by their missing adipose fin or strata fin clips.

Petersen Estimate and Confidence Interval

Chapman's form of the Petersen mark-recapture estimate is used for "instantaneous" population estimates (Seber 1982, p. 60) if the diagnostic tests within the SPAS program do not detect obvious problems with this approach. Let *M* denote the number of fish marked in a random sample of a population of size *N*. Let *C* denote the number of fish examined for marks at a later time, and let *R* denote the number of fish in the second sample with a mark. Then the estimated number of fish in the entire population, *N**, is given by

$$N^* = \frac{(M+1)(C+1)}{(R+1)} - 1. \tag{1}$$

In this equation, *R* is a random variable, and it can be assumed to follow a Poisson, binomial, or hypergeometric distribution, depending on the circumstances of the sampling. Moreover, when *R* is large compared with the size of the second sample, *C*, its distribution can be assumed to be approximately normal (a practical check is to ensure *R* is at least 30 before using the normal approximation). Let $\hat{p}$ be an estimate of the proportion of marked fish in the population such that $\hat{p} = R/C$. We will use approximate confidence interval bounds for $\hat{p}$ based on the assumption that *R* follows a hypergeometric distribution. Define the confidence bounds for $\hat{p}$ as ($a_{0.025}$, $a_{0.975}$). Then the 95% confidence interval bounds for the Petersen population estimate, *N**, are found by taking reciprocals of the confidence interval bounds for $\hat{p}$, and multiplying by *M*. That is, the confidence bounds for the Petersen estimate are given by ($M \cdot 1/a_{0.975}$, $M \cdot 1/a_{0.025}$).

Sample size criteria are given in Seber (1982, p. 63). If $\hat{p} = 0.1$, and the size of the second sample *C* is at least the minimum given in Table 1, a 95% confidence interval for $\hat{p}$ is given by

$$\hat{p} \pm \left[1.96 \sqrt{\left(1 - \frac{C}{\hat{N}}\right) \cdot \hat{p}(1-\hat{p})/(C-1)} + \frac{1}{2C} \right], \text{ (Seber 1982, eq. 3.4).} \tag{2}$$

Table 1. Sample size criteria for using Seber's (1982) eq. 3.4 to find 95% confidence interval for $\hat{p}$. For given $\hat{p}$, minimum sizes for the second sample C are indicated.

$\hat{p}$ (or 1- $\hat{p}$)	0.5	0.4	0.3	0.2	0.1
minimum C	30	50	80	200	600

Seber's (1982) eq. 3.4 may also be used when $\hat{p} < 0.1$ if $R > 50$. If these criteria are not met, the confidence interval bounds for $\hat{p}$ are found from Table 41 in Pearson and Hartley (1966).

RESULTS

Weir Operations

The Speel Lake weir was operational from July 14 to September 18. A total of 7,014 sockeye salmon were counted passing past the weir (Table 2). Of these, 1,444 sockeye salmon were marked with an adipose fin clip, and 1,402 sockeye salmon were sampled for age sex and length. The sockeye salmon passed through the weir in distinct pulses, and high weir counts occurred on July 29, August 2, August 16, and September 2. The 2003 total weir count was below average between 1996 and 2003 (Figure 2).

Increases in rainfall coincided with some of the increases in weir counts during the spawning migration (Table 3; Figure 3), but the effect was not as stark as in earlier years. Changes in water temperature or water level did not coincide well with changes in passage of sockeye salmon through the weir (Figures 4 and 5).

Recapture

Two ADF&G employees made two trips into the lake to examine fish that had passed through the weir, to recapture marked fish, and to take brain parasite and otolith samples. A third trip was scheduled, but was cancelled due to poor weather conditions. During the recovery events, the fish were clustered at the end of the lake away from the outlet.

The first trip lasted from September 16 to September 18. The crew, with assistance of several DIPAC employees, was able to examine 835 sockeye salmon in three days. Since spawning had barely begun, no spawned-out fish or carcasses were available; the crew therefore did not take brain parasite or otolith samples. Due to a misunderstanding, no sex or length information was recorded for these fish. The sampled fish were stratified by size, based on the crew leader's judgment call, and the data were recorded for the individual strata (Table 4). All fish examined in the 1st recovery trip were marked with a dorsal fin clip and released.

The second recovery trip took place on September 30 and October 1. The sampling crew consisted of the two ADF&G employees. On this trip, length and sex data were recorded, and all fish examined were given an anal fin clip. Of the 314 sockeye salmon examined on the second trip, 61 fish had been captured during the first recovery trip, 49 fish had been marked at the weir, and 10 of the 49 fish originally marked at the weir been captured during the first recovery trip (Table 5).

Data Analysis

Comparisons of the lengths of marked fish and fish in the second recapture confirmed that small fish were swimming through the weir (Table 6; Figure 6). Surprisingly, the size range of recaptured fish was restricted on both ends; the size range at the weir was 330 mm to 640 mm, while the smallest size recaptured was 420 mm, and the largest recaptured was 590 mm. ADF&G biologists believe that the weir selects larger fish, by allowing small fish to swim through the weir unimpeded. Even when the length range was restricted to 420-590 mm, the cumulative proportions for marked fish and recaptured fish still exhibited possible size selectivity (Figure 7). Some of the difference may be due to the low numbers of recaptured fish in the size range of 465-520 mm. The seine used in the recovery events is not known to be size selective for adult sockeye salmon. I decided to restrict the population estimate to fish greater than 420 mm (mid-eye to fork length), instead of bracketing the population estimate by excluding both smaller and larger fish.

The information from both the first and second recovery events was used in the calculations of abundance, using SPAS. I assumed that the size cutoff between small and large fish was the same for both recovery events, 420 mm. This assumption was necessary, if the data from the first recovery event were to be included. The population estimates using Darroch, least squares, Schaefer and pooled Petersen methods were all between 8,480 and 8,720 fish for all estimates. Therefore, I chose to use the Pooled Petersen estimate of 8,486 sockeye salmon (greater than 420 mm in length), for the Speel Lake escapement. The 95% confidence interval was 7,446 to 9,729. The weir count is about 430 fish less than the lower end of the confidence interval, when using all recovery data. The Petersen estimate for the second event alone was 7,374 sockeye salmon over 420 mm in length, with a confidence interval of 5,885 fish to 10,326 sockeye salmon.

DISCUSSION

From the results of previous mark-recapture studies at Speel Lake, ADF&G biologists concluded that Speel Lake weir allows sockeye jacks to pass between the pickets uncounted. I believe that some proportion of the larger fish may also pass the weir without being counted, based on the results of the 2003 two-event mark-recapture study. However, the results of the 2003 mark-recapture study are not conclusive, since length data were not taken during the first recovery event. When I only used data from the second recovery event, the estimate was closer to the weir count. To provide concrete evidence for or against the theory that larger fish are bypassing the weir, the 2004 mark-recapture study must include taking length measurements from all fish examined in the recovery event, as well as length measurements for all fish marked.

In previous years, temporal rainfall patterns exerted a compelling influence on salmon migration past the Speel lake weir (Riffe and Clark 2003). While the 2003 weir counts had pulses that did not coincide with rainfall events, rainfall was still an important factor in triggering fish passage.

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Table 2. Number of sockeye salmon counted, marked, and sampled, water temperature, and water level by day, at Speel Lake weir, in 2003.

Date	No. Sockeye Counted	No. Sockeye Marked	No. Sockeye Sampled for Scales	Water Temp. in Celsius	Water Level in Cm.
7/14	0	0	0	-	-
7/15	0	0	0	-	-
7/16	0	0	0	-	-
7/17	0	0	0	-	-
7/18	0	0	0	-	-
7/19	8	0	0	-	-
7/20	0	0	0	-	-
7/21	5	0	0	-	-
7/22	3	0	0	19.9	20.0
7/23	9	5	0	17.4	18.0
7/24	2	0	0	15.5	17.0
7/25	42	8	10	17.7	13.0
7/26	56	12	10	17.6	12.0
7/27	286	57	45	17.0	13.5
7/28	624	105	80	16.8	13.5
7/29	150	90	90	16.6	16.0
7/30	87	20	20	16.6	21.0
7/31	198	40	40	16.8	19.0
8/1	325	65	65	17.2	18.0
8/2	892	180	180	16.5	16.9
8/3	31	0	0	16.5	16.5
8/4	18	10	10	15.5	15.2
8/5	66	13	13	15.8	15.5
8/6	209	40	40	16.1	14.5
8/7	382	77	77	16.5	13.0
8/8	156	30	30	17.9	12.0
8/9	71	14	14	18.0	10.5
8/10	4	0	0	17.2	9.0
8/11	39	8	8	16.6	8.5
8/12	52	11	11	17.4	7.5
8/13	139	28	28	17.1	7.5
8/14	304	61	61	17.2	7.0
8/15	538	108	108	17.0	8.5
8/16	360	72	72	16.5	17.0
8/17	32	6	6	16.2	22.0
8/18	0	0	0	16.2	27.0
8/19	21	4	4	16.0	28.0
8/20	48	6	6	16.0	28.0
8/21	35	7	7	15.1	38.0
8/22	11	2	2	14.5	37.5
8/23	14	3	3	14.6	35.5
8/24	10	2	2	14.5	33.0
8/25	19	4	4	14.5	31.5
8/26	15	3	3	14.5	29.5
8/27	13	3	3	14.8	31.0
8/28	4	1	1	14.5	32.0
8/29	0	0	0	14.5	30.5
8/30	3	1	1	14.5	30.5
8/31	130	26	26	14.7	30.0
Totals	5,411	1,122	1,080		

Table 2. Page 2 of 2.

Date	No. Sockeye Counted	No. Sockeye Marked	No. Sockeye Sampled for Scales	Water Temp. in Celsius	Water Level in Cm.
9/1	223	44	44	14.0	34.5
9/2	710	142	142	14.1	58.0
9/3	67	14	14	13.9	67.5
9/4	42	8	8	13.7	65.0
9/5	35	7	7	13.6	60.0
9/6	45	12	12	13.7	54.5
9/7	30	5	5	13.7	51.0
9/8	26	6	6	13.4	53.5
9/9	54	11	11	13.2	61.0
9/10	78	15	15	13.1	57.5
9/11	12	2	2	13.0	58.5
9/12	18	4	4	12.9	66.0
9/13	67	13	13	12.6	61.5
9/14	159	32	32	12.0	76.0
9/15	31	6	6	11.4	72.5
9/16	4	1	1	10.1	64.0
9/17	2	0	0	10.5	59.0
9/18	0	0	0	10.5	55.5
Grand Total	7,014	1,444	1,402		

Table 3. High and low temperature, and rainfall, by day, at Snettisham Hatchery in 2003.

Date	Temp. in Celsius High	Temp. in Celsius Low	Daily Rain in Cm.	Date	Temp. in Celsius High	Temp. in Celsius Low	Daily Rain in Cm.
7/14	16	13	0.1	8/16	13	11	5.8
7/15	16	12	0.0	8/17	16	11	5.0
7/16	12	12	0.1	8/18	13	11	0.1
7/17	13	11	2.1	8/19	16	9	0.8
7/18	22	10	0.4	8/20	9	9	1.4
7/19	22	13	0.0	8/21	16	7	4.6
7/20	17	11	0.0	8/22	16	5	0.4
7/21	17	11	1.6	8/23	12	6	0.0
7/22	17	10	1.4	8/24	12	9	0.5
7/23	21	9	0.1	8/25	20	7	0.4
7/24	19	12	0.0	8/26	20	7	0.0
7/25	18	12	0.0	8/27	13	9	0.0
7/26	15	11	0.0	8/28	18	9	0.3
7/27	16	12	1.2	8/29	17	9	0.0
7/28	17	11	0.3	8/30	19	10	0.2
7/29	17	10	3.6	8/31	13	9	2.3
7/30	20	12	0.1	9/1	13	9	4.0
7/31	12	11	0.0	9/2	13	10	8.5
8/1	13	11	0.4	9/3	13	11	3.7
8/2	12	10	0.5	9/4	13	10	0.9
8/3	16	10	1.7	9/5	16	6	0.0
8/4	13	11	0.0	9/6	10	8	0.4
8/5	19	9	1.3	9/7	12	9	1.0
8/6	23	11	0.0	9/8	15	11	5.0
8/7	24	11	0.0	9/9	11	9	3.2
8/8	27	12	0.0	9/10	15	9	0.3
8/9	24	11	0.0	9/11	11	11	4.3
8/10	23	10	0.0	9/12	11	10	1.8
8/11	21	12	0.0	9/13	12	9	1.7
8/12	15	12	0.0	9/14	10	8	3.9
8/13	16	12	0.6	9/15	9	7	1.3
8/14	13	12	0.9	9/16	12	2	0.0
8/15	15	13	2.9	9/17	13	2	0.3
				9/18	10	4	0.5

Table 4. Summary of information obtained during recovery phase of the 2003 Speel Lake sockeye salmon mark-recapture study, stratified by size.

	Recovery Trip #1	Recovery Trip #2
Date	Sept. 16-18	Sept. 30 - Oct. 1
Large Fish		
No. Examined	732	244
No. Marked	119	47
Percent Marked	16.3%	19.3%
No. Previously Recovered	n.a.	50
No. of Previously Recovered with marks	n.a.	9
Small Fish		
No. Examined	103	70
No. Marked	0	2
Percent Marked	0.0%	2.9%
No. Previously Recovered	n.a.	10
No. of Previously Recovered with marks	n.a.	1
Total No. Fish Examined	835	314

Table 5. Number of fish by length that were examined during the marking and second recovery event of the 2003 Speel Lake sockeye salmon mark-recapture study. The second event recaptures are fish caught during the second recovery event that had been marked at Speel Lake weir.

Length	Marking at Weir	2nd Recovery Event	2nd Event Recaptures	Length	Marking at Weir	2nd Recovery Event	2nd Event Recaptures
300		2		475	22	9	2
305		4		480	43	5	
310		5		485	17	2	1
315		6		490	33		
320		6		495	12	3	
325		4		500	36	2	
330	1	7		505	14	4	2
335		6		510	31	4	1
340		9		515	6	2	
345		2		520	18	5	
350	1	1		525	6	3	1
355		2		530	23	13	6
360		2		535	9	7	2
365		1		540	41	10	4
370		1		545	10	9	1
375				550	58	16	1
380				555	13	9	3
385				560	90	13	2
390				565	37	7	
395				570	101	3	2
400				575	37	4	1
405				580	116	6	2
410	1	4		585	37	1	
415	1	4	1	590	95	2	1
420	7	4	2	595	22	2	
425	6	9	1	600	70		
430	18	11	1	605	12		
435	5	11	1	610	30		
440	30	16	1	615	5		
445	14	11		620	14		
450	59	11	4	625			
455	38	11	3	630	6		
460	63	8	3	635			
465	36	6		640	2		
470	56	9					
				Totals	1,402	314	49

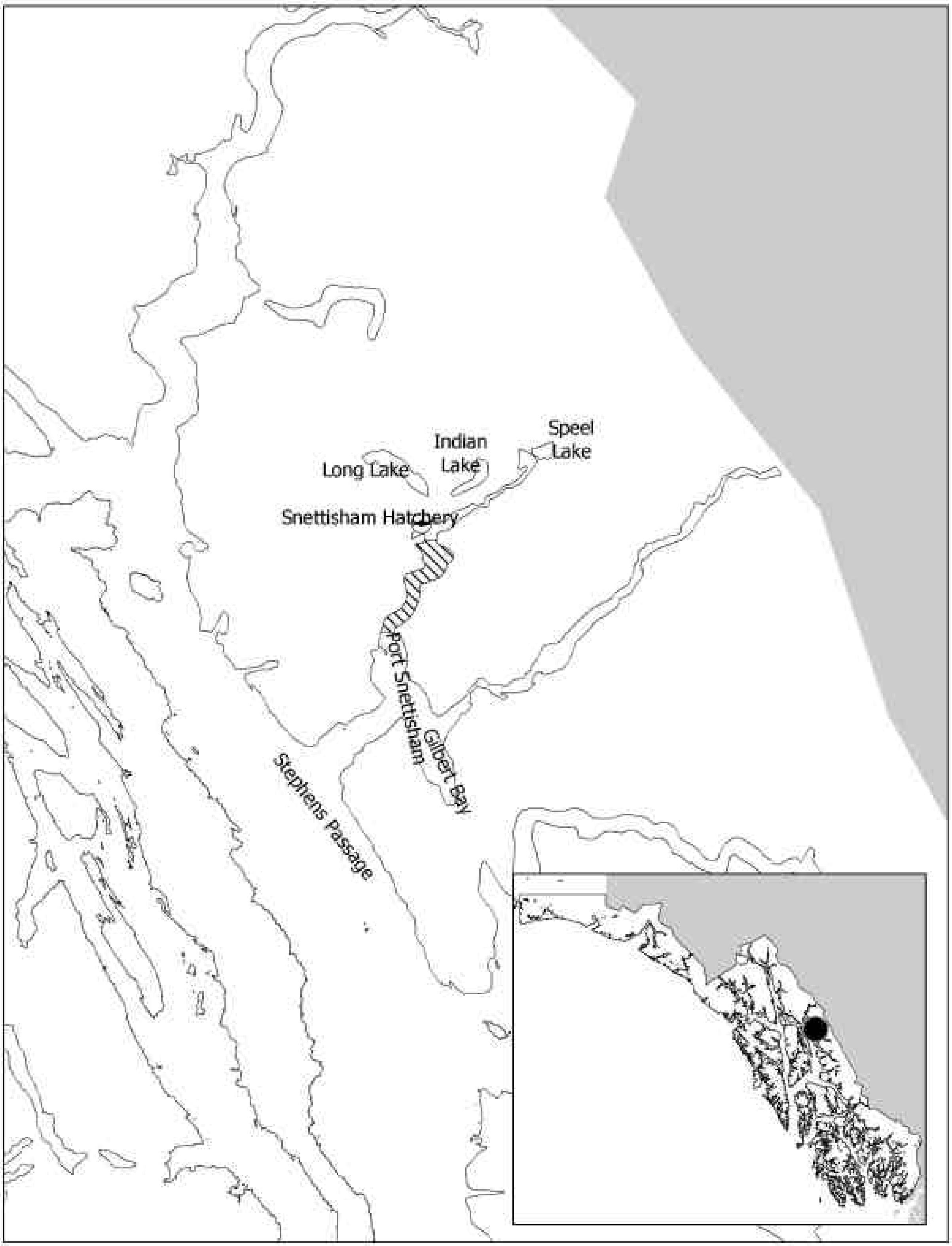

Figure 1. Map of Speel Lake and surroundings, with inset of Southeast Alaska. Striped area denotes the hatchery Special Harvest Area (SHA).

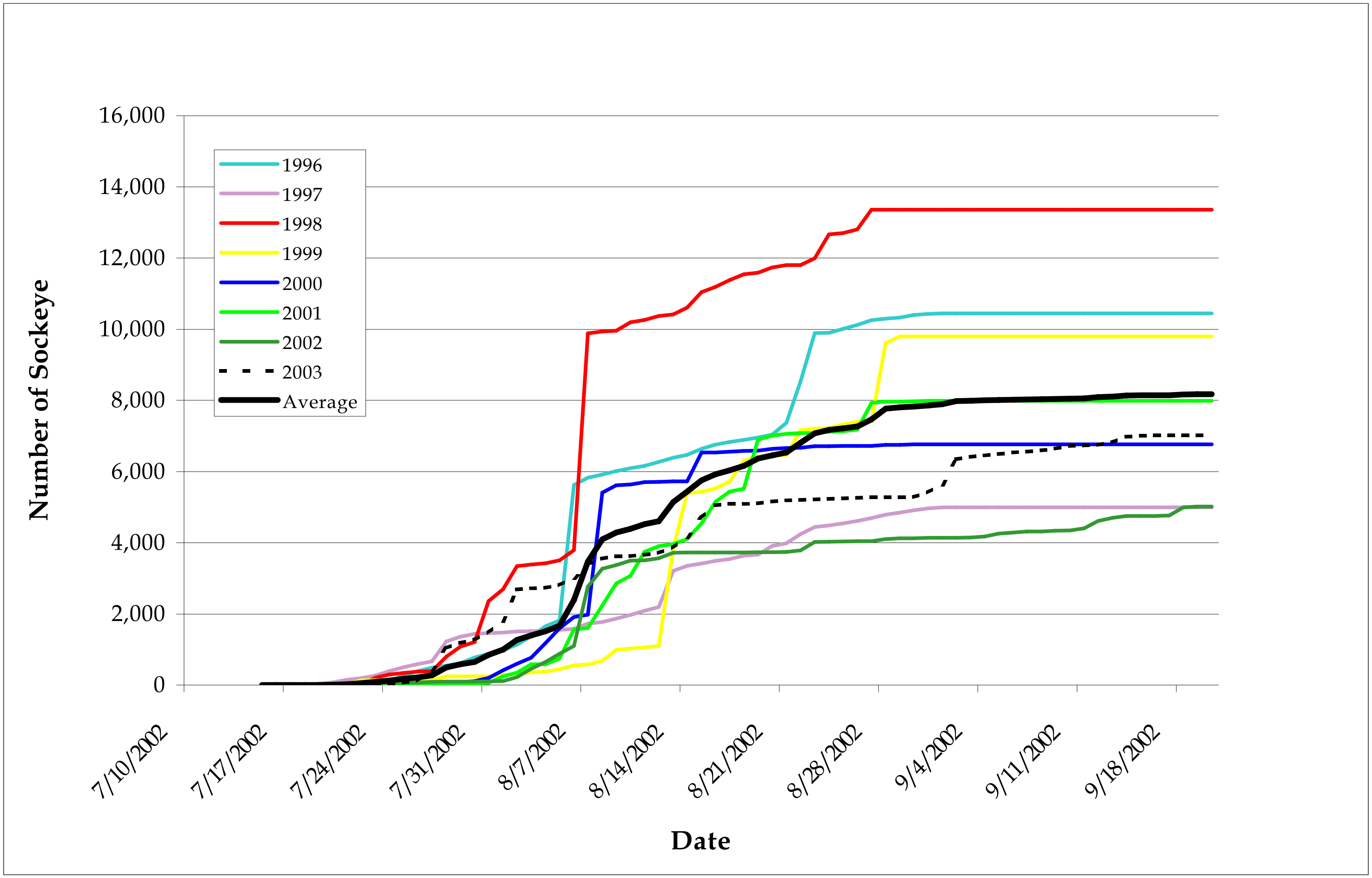

Figure 2. Cumulative daily weir counts for Speel Lake sockeye salmon, from 1996 to 2003.

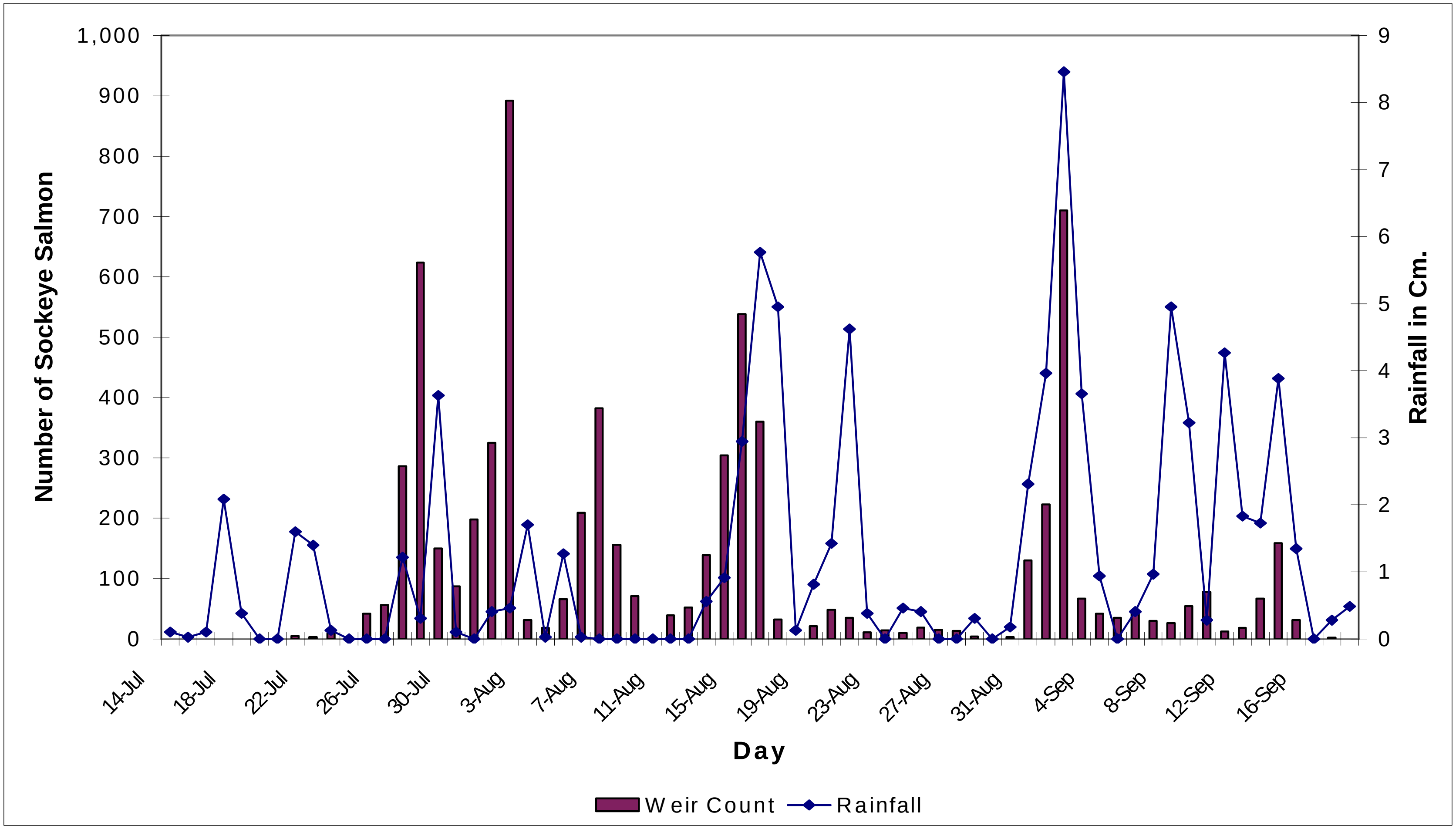

Figure 3. Number of sockeye salmon per day passing Speel Lake weir, and amount of rainfall in centimeters falling at Snettisham hatchery in 2003.

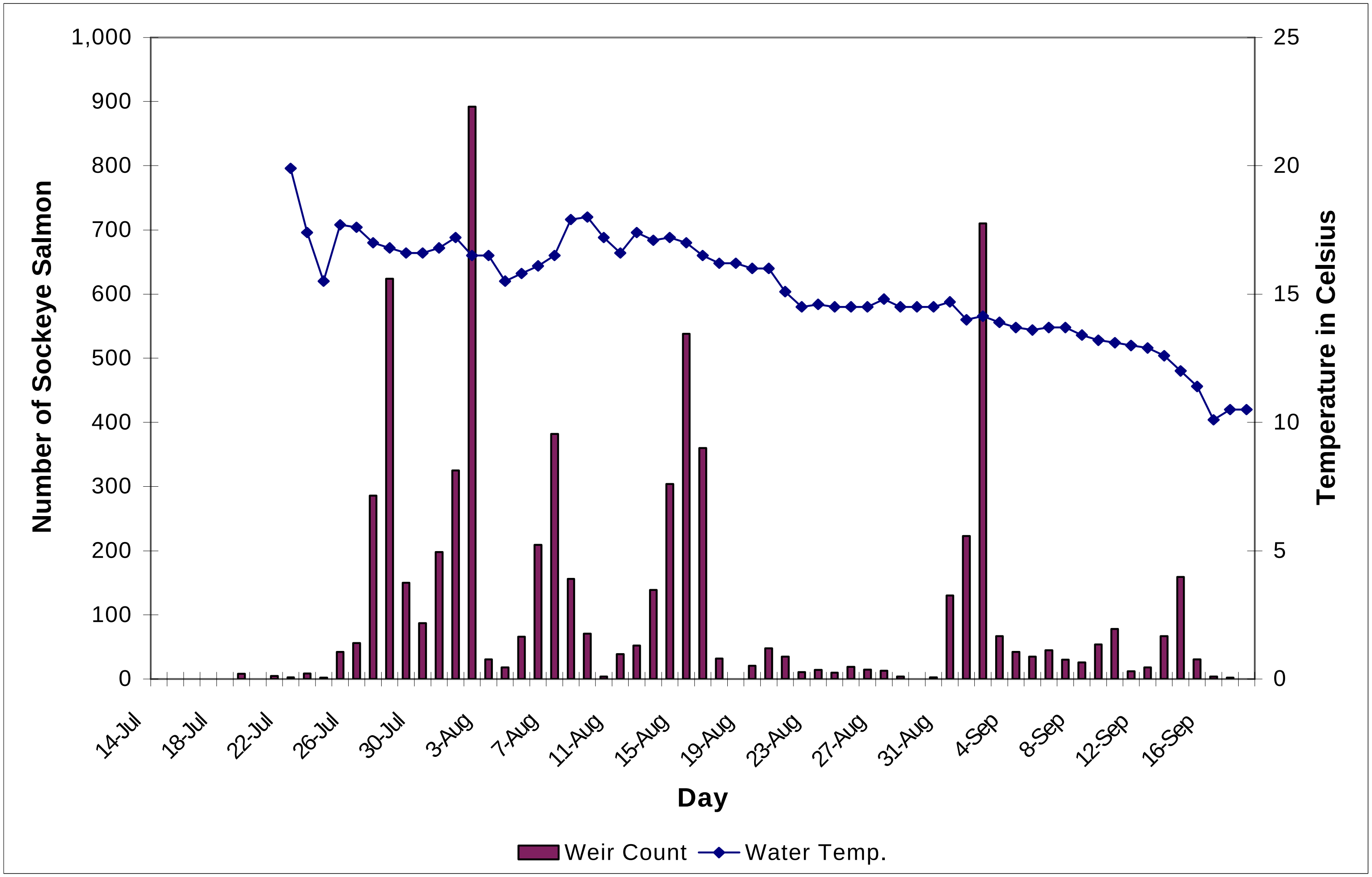

Figure 4. Number of sockeye salmon per day passing Speel Lake weir, and water temperature in degrees Celsius at Speel Lake weir in 2003.

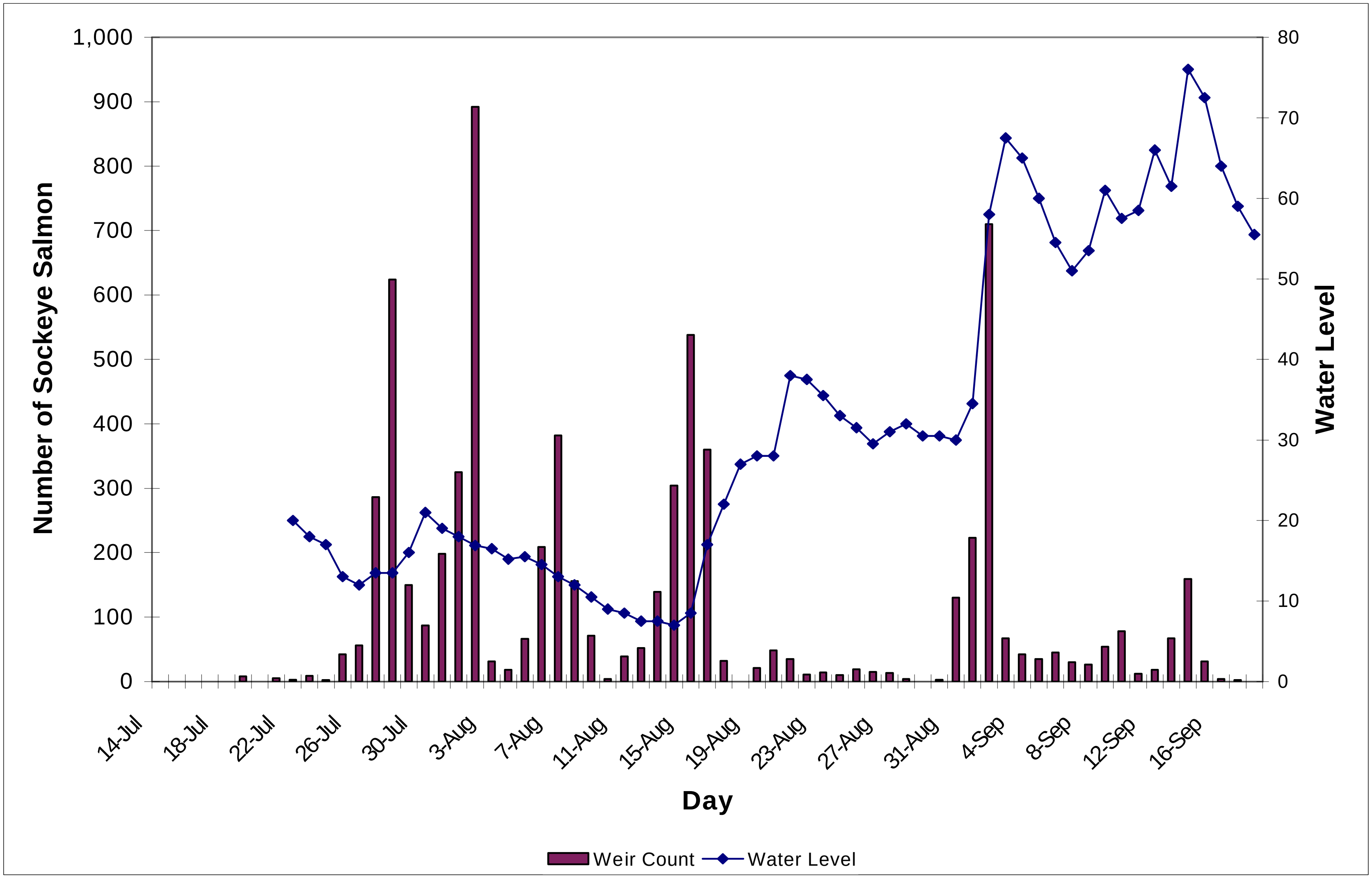

Figure 5. Number of sockeye salmon per day passing Speel Lake weir, and water level in centimeters at Speel Lake weir in 2003.

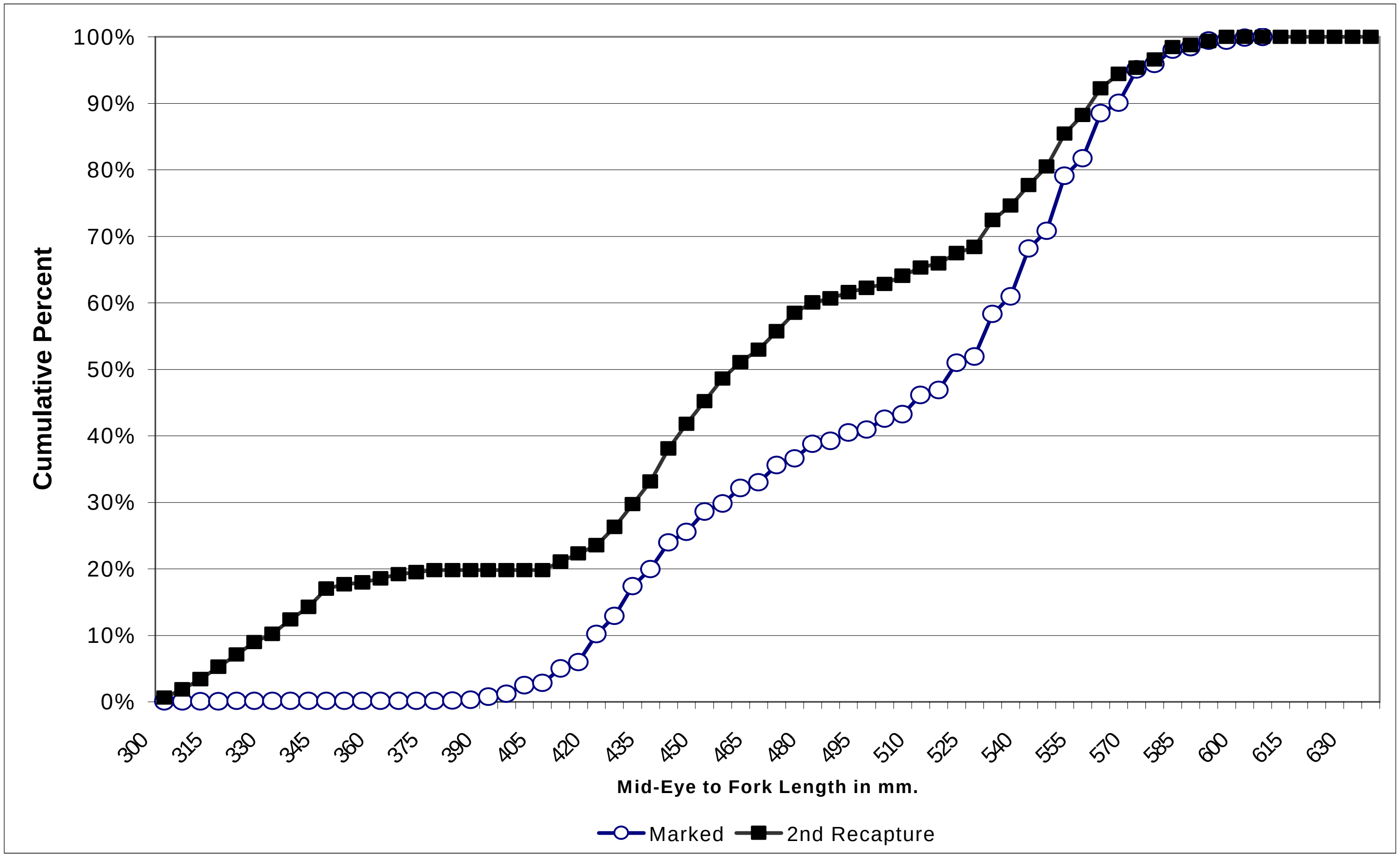

Figure 6. Comparison of cumulative percent by length of sockeye salmon marked at Speel Lake weir, and of sockeye salmon examined on Speel Lake spawning grounds, in 2003.

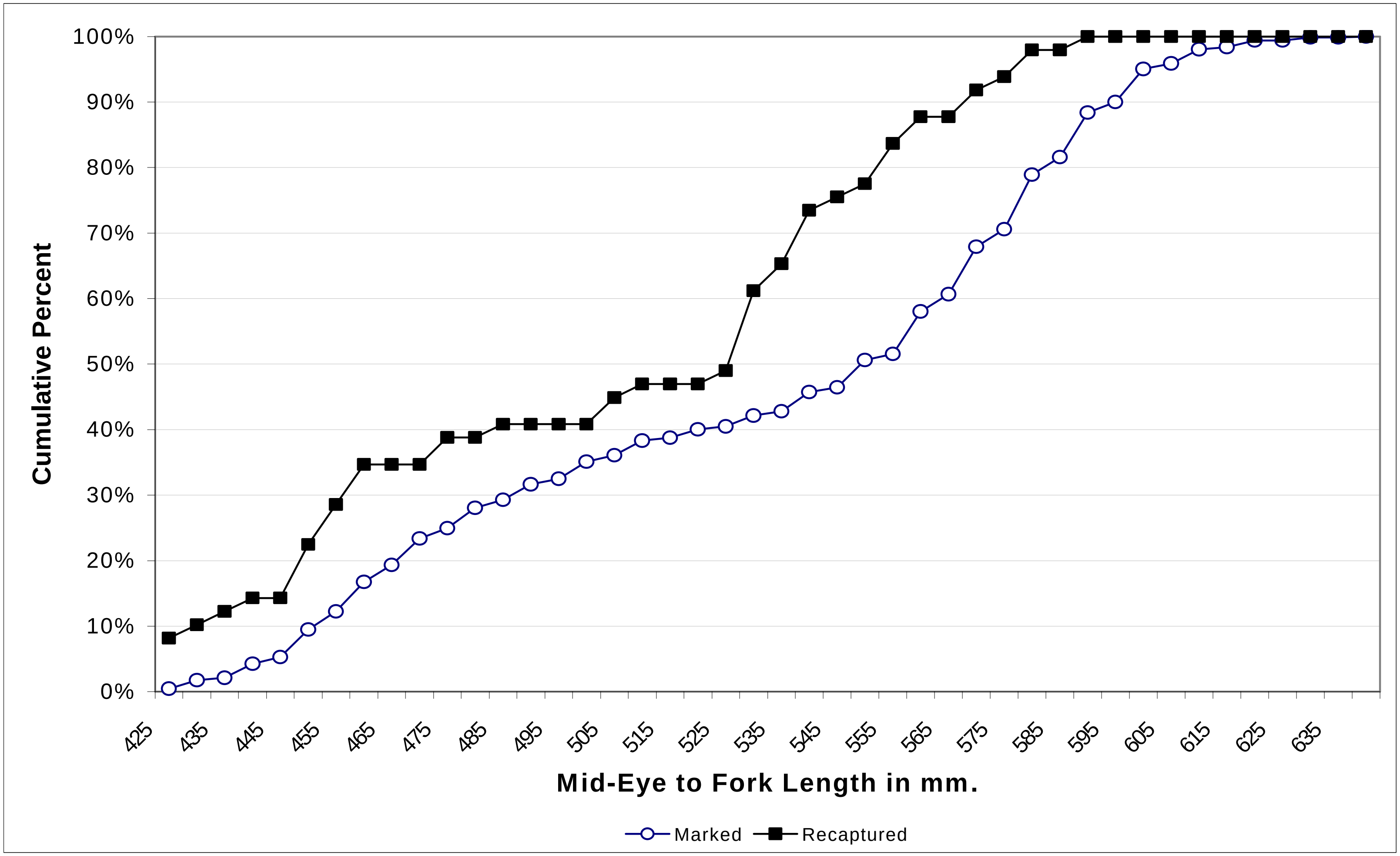

Figure 7. Comparison of cumulative percent by length above 420 mm, of sockeye salmon marked at Speel Lake weir, and of sockeye salmon examined on Speel Lake spawning grounds, in 2003.